(NASA-CR-175794) HARDWARE TEST PROGRAM FOR EVALUATION OF BASELINE RANGE-RANGE RATE SENSOR CONCEPT Monthly Progress Report, 12 Apr. - 11 May 1985 (Bendix Aerospace Systems Div.) 10 p HC A02/MF A01 CSCL 14B G3/35

N85-27193

Unclas

22818

HARDWARE TEST PROGRAM FOR EVALUATION OF BASELINE RANGE/RANGE RATE SENSOR CONCEPT MONTHLY PROGRESS REPORT

12 APRIL THROUGH
11 MAY 1985

CONTRACT NAS8-36144

PREPARED FOR:

NATIONAL AERONAUTICS AND
SPACE ADMINISTRATION
GEORGE C. MARSHALL
SPACE FLIGHT CENTER
MARSHALL SPACE FLIGHT
CENTER, ALABAMA 35812

PREPARED BY:

ALLIED BENDIX AEROSPACE
BENDIX GUIDANCE SYSTEMS DIV.
MISHAWAKA OPERATIONS
400 SOUTH BEIGER STREET
MISHAWAKA, INDIANA 46544

1.0 INTRODUCTION

The Hardware Test Program for evaluation of the baseline range/range rate sensor concept was initiated 11 September 1984. This is the eighth report period (12 April through 11 May) since that award.

During this report period, evaluation of the Interrupted CW (ICW) mode of operation continued with emphasis on establishing the sensitivity of the video portion of the receiver. Results of the tests indicate that the sensitivity of the video portion of the receiver was 7 dB less than the theoretical value. This departs from test results of previous implementations in which achieved sensitivity was within 1.5 to 2 dB of the theoretical value. Several potential causes of this discrepancy in performance have been identified and are scheduled for further investigation.

The trade study initiated during the previous period for the purpose of identifying potential savings in $R/\dot{R}$ sensor developmental and per unit costs has been completed. Results of the trade study indicate that a cost savings in both per unit and program costs are realizable by eliminating one of the modes of operation. An acquisition (total program) cost savings of approximately 10% is projected by eliminating the CW mode of operation. The modified $R/\dot{R}$ sensor would operate in the ICW mode only and would provide coverage from initial acquisition at 12 nmi to within a few hundred feet of the OMV. If the ICW mode only were selected, then an accompanying sensor would be required to provide coverage from a few hundred feet to docking.

An additional saving of 28% in acquisition costs could be realized for a CW mode only $R/\dot{R}$ sensor configuration which would provide coverage from a few hundred feet to essentially docking. An accompanying sensor would then be required to provide coverage from the initiation of the rendezvous maneuver to within a few hundred feet of the OMV.

Costing data solicited from vendors during the trade study indicates that the acquisition costs could be higher than the previously quoted estimates. The potential increase in cost is attributed to space qualification requirements which could increase cost by as much as 60%. Additional costing information is presently being solicited in order to establish a viable acquisition cost.

The test program is divided into four major tasks: Analysis, Radar Modification, Testing, and Documentation and Reviews. Progress is reported in the following paragraphs in terms of these four tasks.

2.0 ANALYSIS

The cost trade study initiated during the previous report period has been completed. Results of the study indicate that potential savings in developmental and per unit costs can be realized for modified versions of the Bendix proposed $R/\dot{R}$ sensor. The procedure used in the trade study was to establish the acquisition (total program) cost for the baseline $R/\dot{R}$ sensor,

which combines CW and interrupted CW modes of operation, then acquisition costs for modified versions of the R/R sensor were established for comparison. Three modified versions were considered:an R/R sensor configuration operating in the ICW mode only, a lower power ICW mode only version and a CW mode only configuration. A brief description of the baseline and modified versions of the R/R sensor with cost comparisons is presented in the following paragraphs.

Baseline R/R Sensor. The baseline sensor combines ICW and CW modes of operation to provide continuous range coverage from 12 nmi during the rendezvous maneuver, to docking at essentially zero range. Separate transceivers are utilized by the ICW and the CW portions of the R/R sensor which share a common data processor. The ICW transceiver containing the millimeter and microwave components of the sensor, is integrated with a gimbaled antenna mounted on a mast above the OMV vehicle. Utilizing a 500 mW solid state 94 GHz transmitter and 16 inch aperture, the baseline sensor searches a 30° by 8 nmi volume during initial acquisition, and following acquisition, tracks the spacecraft target in angle, using monopulse processing, in range and in doppler until the target is within approximately 1 m of the OMV.

The CW transceiver and two 30° antennas (transmitter and receiver) are located in the vicinity of, and are aligned with, the docking mechanism. Utilizing a 160 mW solid state 94 GHz transmitter, the CW portion of the sensor is capable of accurately range and doppler tracking a 1 m^2 target during the final 75 meters of the docking maneuver. The low gain transmitter and receiver antennas are nongimbaled and provide 30° angle coverage.

The baseline sensor described above which combines ICW and CW modes of operation served as the reference configuration for establishing acquisition costing data.

ICW Only R/R Sensor. By eliminating the CW portions of the baseline sensor, the ICW only sensor provides coverage from initial acquisition, during rendezvous, to a range within 75 m of docking. A companion sensor could be utilized to provide range coverage in the range interval of 75 m to docking.

Reduced Power ICW Only R/R Sensor. One of the major sensor cost items is the 500 mW solid state transmitter. Realizing the 500 mW at the antenna port requires an 800 mW source because of internal losses between the source and antenna. Since a single diode Impatt source is capable of generating 200 mW, a power combiner is required to achieve the required 800 mW, and as anticipated, there is a corresponding cost increase which accompanies the power increase. A variation of the ICW mode configuration considered in the trade study was a reduced power 125 mW transmitter achievable with a single device Impatt source. The reduced power version

of the ICW $R/\dot{R}$ sensor would provide the same performance as the high power configuration for a given target size at a reduced range (70% of the full power range) or it will provide the same range capability as the full power configuration for a 6 dB larger target.

<u>CW Only $R/\dot{R}$ Sensor</u>. By removing the ICW portions of the baseline sensor, the resulting CW only configuration provides coverage during the final docking maneuver in the range interval of 75 m to 1 m.

In either case of the modified versions considered, an accompanying sensor or alternate technique would be required to provide the eliminated function.

The program and per unit costs for each of the $R/\dot{R}$ sensor configurations described were established by itemizing the costs associated with designing and developing the $R/\dot{R}$ sensor, as well as the individual component and assembly costs per unit. The individual categories and corresponding percent of total ROM acquisition cost are listed in Table I. The resulting cost schedule represents the best estimate available which will provide the space qualified sensor required for this application.

TABLE I

BASELINE $R/\dot{R}$ SENSOR
ROM COSTING SCHEDULE

ITEM	% OF TOTAL COST
1. EI Lab Unit	7.8%
2. Qualification Unit	10.9
3. Qualification Test	2.6
4. Special Tools and Test Equipment	3.2
5. Non-Recurring Costs	62.1
6. NASA-MSFC Nuclear Hardening Requirements	5.6
7. Flight Unit	7.8
TOTAL ACQUISITION COST	100.0%

Using the baseline R/Ṙ sensor as a reference, the relative acquisition costs for the modified sensor configurations are listed in Table II.

TABLE II

R/Ṙ SENSOR CONFIGURATION
COST COMPARISONS

CONFIGURATION DESCRIPTION	ACQUISITION COSTS	PERCENT REDUCTION
ICW/CW BASELINE	100%	-
ICW ONLY	90	10%
REDUCED POWER ICW ONLY	86	14
CW ONLY	62	38

It will be noted that an acquisition cost number was not included in Table I. Before a final cost estimate can be provided there are several items such as the millimeter wave and microwave components and the antenna platform, for which additional cost data must be accumulated. The vendor ROM costing data solicited for this cost study indicates that development and per unit costs could be notably higher than those used in previous cost estimates. The increase is attributed to the requirement for space qualification.

A comparison of the cost of a space qualified vs. a non-qualified design indicates up to a 60% increase in total acquisition costs. Additional sources are being queried in an attempt to assure the viability of our final cost numbers prior to publication.

3.0 RADAR MODIFICATIONS

No radar modifications were made during this report period.

4.0 TESTING

Formal testing for performance evaluation of the interrupted CW (ICW) mode of operation continued during the report period. Emphasis was placed on evaluation of the video portion of the receiver in order to establish the source of discrepancy between predicted and measured

sensitivity reported in last month's progress report. Transmitter-receiver leakage tests were likewise completed during the report period.

Sensitivity Tests

The theoretical sensitivity of the video portion of the receiver is dependent upon the noise power at the video amplifier input and the gain of the correlator. The relationship expressing the resulting SNR's at the video input and correlator output,

$$(S/N)_o = \frac{G_c\ (S/N)_i}{1 + (S/N)_i} \tag{1}$$

where $(S/N)_o$ is the SNR at correlator output

G_c is the correlator gain, and

$(S/N)_i$ is the SNR at correlator input

Performance of the video portion of the receiver (video amplifier and correlator) was evaluated in terms of the ratio of output-to-input SNR. The correlator gain may then be expressed in terms of the SNR's,

$$G_c = \left[1 + (S/N)_i\right]\ (S/N)_o/(S/N)_i \tag{2}$$

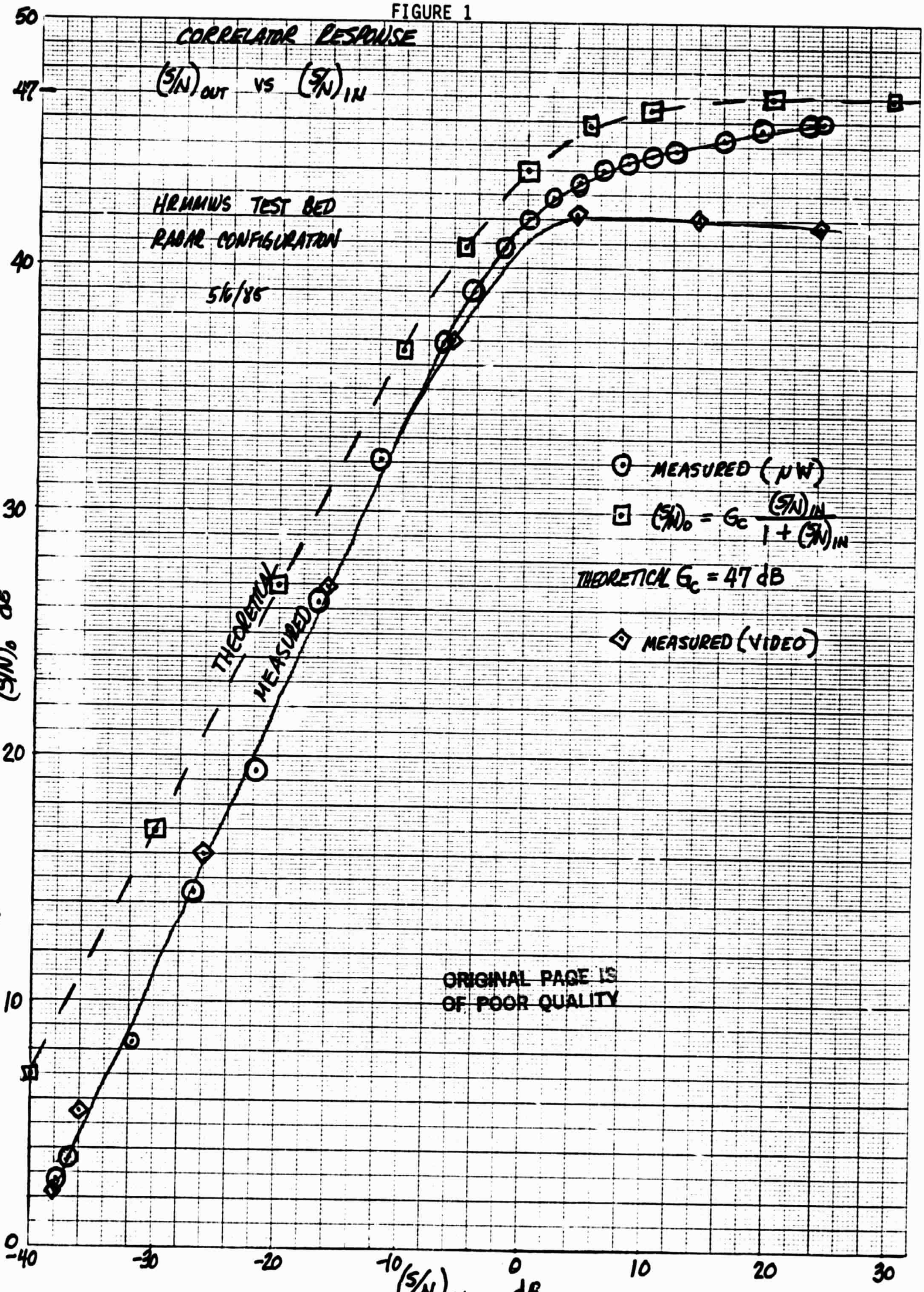
The theoretical correlator gain for the HRMMWS test bed radar configuration is 47 dB. A plot of the measured correlator response for the HRMMWS test bed radar is shown in Figure 1, and the corresponding correlator gain vs. input SNR is shown in Figure 2.

The graph of correlator gain vs. input SNR (Figure 2) depicts the theoretical gain and the typical gain expected. Also shown are the correlator gain measured through the microwave section and through just the video section of the HRMMWS test bed radar. At low $(S/N)_{in}$ the correlator gain is 7 dB lower than the theoretical value. This would account for the fact that all previously reported sensitivity measurements were 6 to 8 dB lower than the predicted value.

Several potential sources of correlator gain deficiency have been suggested for further investigation:

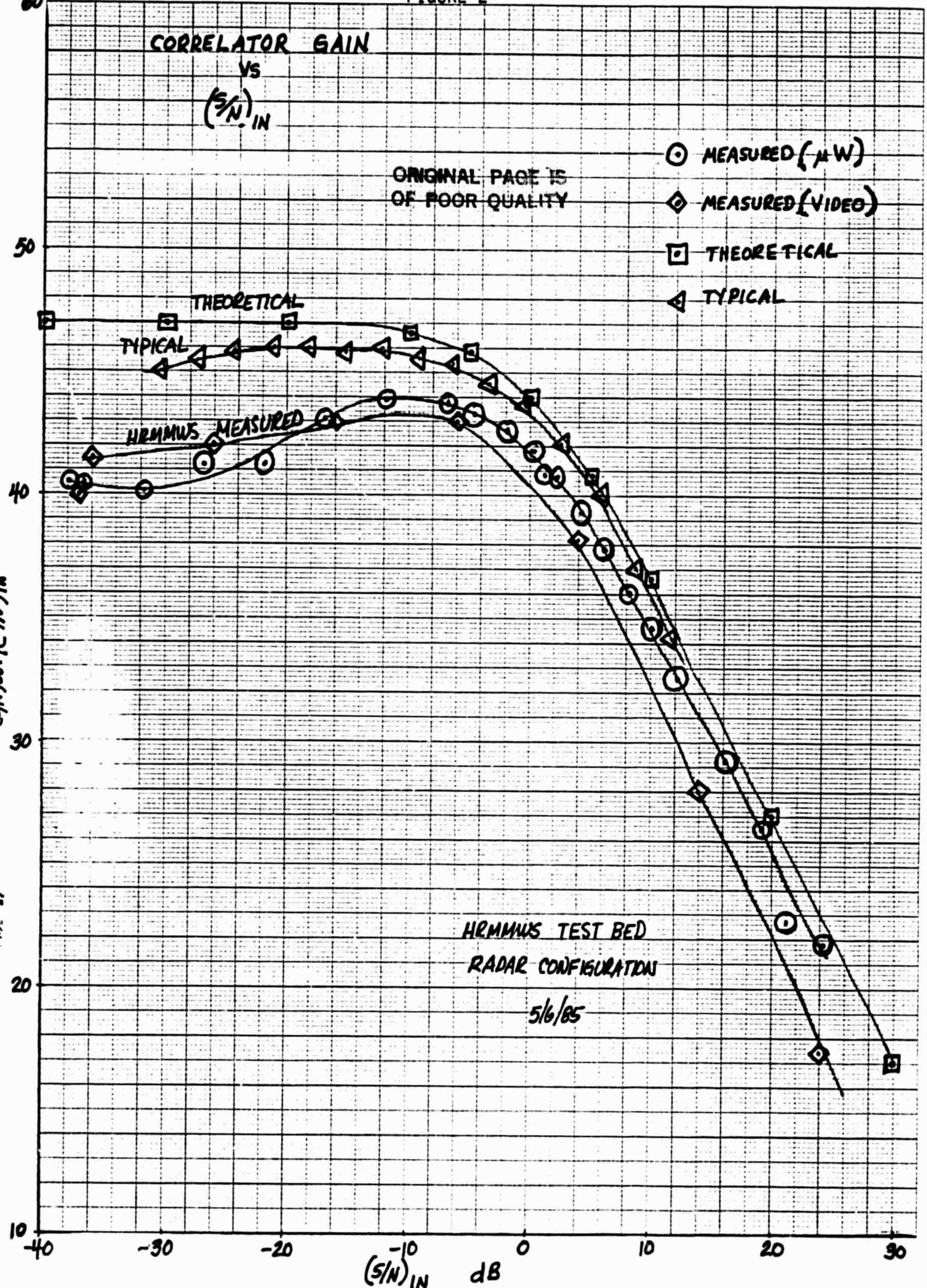
1. Dynamic range limitation. The ECL gate which performs the actual correlation has a maximum voltage swing of 1 volt peak-to-peak. This may not be adequate to realize the full 47 dB of gain.

FIGURE 1



CORRELATOR RESPONSE
(S/N)OUT VS (S/N)IN
HRMMWS TEST BED
RADAR CONFIGURATION
5/6/85
MEASURED (μW)
(S/N)o = Gc (S/N)IN / 1 + (S/N)IN
THEORETICAL Gc = 47 dB
MEASURED (VIDEO)
THEORETICAL
MEASURED
(S/N)o dB
(S/N)IN dB
50
47
40
30
20
10
0
-40
-30
-20
-10
0
10
20
30
ORIGINAL PAGE IS OF POOR QUALITY

FIGURE 2


CORRELATOR GAIN
VS
(S/N)IN
MEASURED (μW)
MEASURED (VIDEO)
THEORETICAL
TYPICAL
ORIGINAL PAGE IS
OF POOR QUALITY
THEORETICAL
TYPICAL
HRMMWS MEASURED
HRMMWS TEST BED
RADAR CONFIGURATION
5/6/85
(S/N)OUT/(S/N)IN dB
(S/N)IN dB
60
50
40
30
20
10
-40
-30
-20
-10
0
10
20
30

2. Extraneous noise. Noise from the PRF generator and the reference delay clock may be getting into the correlator channel and thereby increasing the quiescent noise level.

3. Excess noise bandwidth. The bandwidth of the video amplifiers is 150 MHz. The minumum bandwidth required is 125 MHz (twice the frequency of the 62.5 MHz sampled biphase noise). The 25 MHz excess bandwidth may introduce additional noise at the correlator input.

4. Detector characteristic. The detector following the correlator filter may not provide a true RMS output and thereby potentially introduces a bias.

5. DC coupling. The correlator gate, bandpass filter and detector which have previously been a.c. coupled are d.c. coupled for this implementation. This may likewise introduce a bias.

These potential causes of degraded sensitivity will be investigated in greater detail and the results of that investigation reported at a future date.

Transmitter-Receiver Leakage Tests

Transmitter power which appears at the receiver input due to extraneous coupling between the transmitter and receiver is known as leakage. The measured leakage power in the ICW mode was 5 dB below receiver noise power. A 1 dB reduction in sensitivity is attributable to this level of leakage.

The major source of transmitter-receiver leakage has been isolated to interconnecting cables. Since a major portion of the leakage occurs between the coaxial cables going to and from the millimeter wave portion of the radar, it is anticipated that the leakage can be significantly reduced by appropriate shielding and separating the cables associated with the transmitter and receiver. Additional isolation could be achieved by enclosing the microwave receiver components in a shielded enclosure. Transmitter-receiver isolation could likewise be increased by the addition of a P/N diode switch in both the transmitter before the injection locked amplifier and in the receiver blanking section.

5.0 DOCUMENTATION REVIEWS

No documentation was completed during this report period.

6.0 PLANS FOR NEXT REPORT PERIOD

The next report period will be spent preparing the final report.

7.0 COSTS AND PERCENT CONTRACT COMPLETION

Costs

The program expenditures will be reported on a monthly basis. The expenditures through April 1985 were $81,720.

Percent Completion

The estimated physical completion of the contract through the reporting period is 80%.